Section 1

Energy in Earth's Atmosphere

Objectives

After this lesson, students will be able to

I.2.1.1 State in what form energy travels from the sun to Earth.

I.2.1.2 Explain what happens to the sun's energy in the atmosphere and at Earth's surface.

Target Reading Skill

Sequencing Explain that organizing information from beginning to end helps students understand a step-by-step process.

Answers

One way that students might organize the information is by filling in additional boxes as follows:

Some of the sun's energy is reflected back into space or absorbed by gases or particles in the air.

The remaining energy is absorbed or reflected by the surface.

Much of the energy absorbed by the surface is radiated back into the atmosphere.

All in One Teaching Resources

- Transparency I10 L1

Preteach

Build Background Knowledge L1

Heat From the Sun

Encourage students to think about the way the sun heats Earth's surface. Ask: **Which is cooler on a hot, sunny day, a lawn or a parking lot?** *(A lawn)* **Why doesn't the lawn get as hot as the parking lot?** *(Accept all reasonable responses.)* Explain that grass absorbs less heat than pavement, even when both surfaces receive the same amount of sunlight. As a result, the grass does not get as hot. Such differences in the heating of Earth's surface, on a large scale, are the major cause of Earth's weather.

Help Students Read L1

Summarizing Tell students that summarizing the material in this section will help them pull together the main ideas. Allow students to choose whether they would like to present an oral, written, or pictorial summary.

Section 1

Energy in Earth's Atmosphere

Reading Preview

Key Concepts

- In what forms does energy from the sun travel to Earth?
- What happens to the sun's energy when it reaches Earth?

Key Terms

- electromagnetic waves
- radiation
- infrared radiation
- ultraviolet radiation
- scattering
- greenhouse effect

Target Reading Skill

Sequencing As you read, make a flowchart that shows how the sun's energy reaches Earth's surface. Put each step of the process in a separate box in the order in which it occurs.

How Earth's Atmosphere Gets Energy

Sun gives off energy.

↓

Energy travels to Earth as electromagnetic radiation.

↓

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Lab zone Discover Activity

Does a Plastic Bag Trap Heat?

1. Record the initial temperatures on two thermometers. (You should get the same readings.)
2. Place one of the thermometers in a plastic bag. Put a small piece of paper in the bag so that it shades the bulb of the thermometer. Seal the bag.
3. Place both thermometers on a sunny window ledge or near a light bulb. Cover the bulb of the second thermometer with a small piece of paper. Predict what you think will happen.
4. Wait five minutes. Then record the temperatures on the two thermometers.

Think It Over

Measuring Were the two temperatures the same? How could you explain any difference?

In the deserts of Arizona, summer nights can be chilly. In the morning, the sun is low in the sky and the air is cool. As the sun rises, the temperature increases. By noon it is quite hot. As you will learn in this chapter, heat is a major factor in the weather. The movement of heat in the atmosphere causes temperatures to change, winds to blow, and rain to fall.

Energy From the Sun

Where does this heat come from? Nearly all the energy in Earth's atmosphere comes from the sun. This energy travels to Earth as **electromagnetic waves,** a form of energy that can move through the vacuum of space. Electromagnetic waves are classified according to wavelength, or distance between waves. **Radiation** is the direct transfer of energy by electromagnetic waves.

What kinds of energy do we receive from the sun? Is all of the energy the same? **Most of the energy from the sun travels to Earth in the form of visible light and infrared radiation. A small amount arrives as ultraviolet radiation.**

Lab zone Discover Activity

Skills Focus Measuring L1

Materials 2 thermometers, plastic bag, 2 small pieces of paper, tape

Time 10 minutes

Tips CAUTION: *Advise students to be careful when handling the thermometers.* Make sure that the bulbs of both thermometers are shaded by the pieces of paper from direct rays of light; otherwise, both may show equally high temperatures.

Expected Outcome The thermometer in the bag will show a higher temperature.

Think It Over The plastic bag trapped the sun's heat inside, and this caused the thermometer in the bag to show a higher temperature.

As the sun rises, energy in the form of electromagnetic waves reaches Earth's surface.

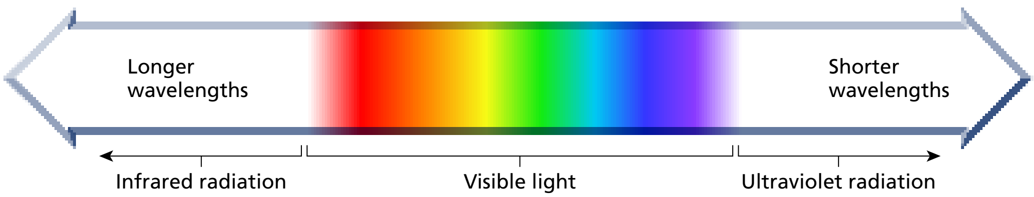

FIGURE 1
Radiation From the Sun
Energy from the sun travels to Earth as infrared radiation, visible light, and ultraviolet radiation.
Interpreting Diagrams *What type of radiation has wavelengths that are shorter than visible light?*

Visible Light Visible light includes all of the colors that you see in a rainbow: red, orange, yellow, green, blue, and violet. The different colors are the result of different wavelengths. Red and orange light have the longest wavelengths, while blue and violet light have the shortest wavelengths, as shown in Figure 1.

Non-Visible Radiation One form of electromagnetic energy, **infrared radiation,** has wavelengths that are longer than red light. Infrared radiation is not visible, but can be felt as heat. The sun also gives off **ultraviolet radiation,** which is an invisible form of energy with wavelengths that are shorter than violet light. Ultraviolet radiation can cause sunburns. This radiation can also cause skin cancer and eye damage.

Reading Checkpoint **Which color of visible light has the longest wavelengths?**

Instruct

Energy From the Sun

Teach Key Concepts L2

Types of Radiation

Focus Point out that Earth receives energy from the sun in the form of different types of radiation.

Teach Ask: **What are the types of radiation that Earth receives from the sun?** *(Visible light, infrared radiation, and ultraviolet radiation)* **How do we detect visible light?** *(We see it.)* **Infrared radiation?** *(We feel it as heat.)* Explain that ultraviolet light cannot be seen directly by humans or felt as heat.

Apply Show students a prism, and explain that its angled sides bend the different colors of visible light into a rainbow. Place the prism in sunlight. Ask: **Where does the light have the shortest wavelength and the longest wavelength?** *(The end with violet light is the shortest, and the end with red light is the longest.)* **learning modality: visual**

Independent Practice L2

All in One **Teaching Resources**

- Guided Reading and Study Worksheet: *Energy in Earth's Atmosphere*
- Transparency I11

Student Edition on Audio CD

Differentiated Instruction

English Learners/Beginning L1
Vocabulary: Science Glossary
Pronounce and define aloud: *radiation, infrared radiation,* and *ultraviolet radiation*, and point to the corresponding part of the spectrum in Figure 1. Have students write definitions of each term in their science glossaries and draw and label their own diagrams of electromagnetic waves. **learning modality: visual**

English Learners/Intermediate L2
Vocabulary: Science Glossary Students can expand on the activity at left by adding the term *electromagnetic waves*. Have students write a sentence for each term and then read their sentences aloud. **learning modality: verbal**

Monitor Progress L2

Drawing Have students draw a diagram of electromagnetic waves, labeling the longer and shorter wavelengths. Have students place their drawings in their portfolios.

Portfolio

Answers
Figure 1 Ultraviolet radiation

Reading Checkpoint Red light

Energy in the Atmosphere

Go Online SCI LINKS NSTA
For: Links on energy in Earth's atmosphere
Visit: www.SciLinks.org
Web Code: scn-0921

Download a worksheet that will guide students' review of Internet resources on Earth's atmosphere.

Teach Key Concepts

The Path of the Sun's Energy L2

Focus Review with students the layers of the atmosphere.

Teach Point out that cloud layers in the troposphere and ozone in the stratosphere absorb some of the sun's radiant energy. Refer students to Figure 2. Ask: **What percentage of solar energy is reflected back to space by the atmosphere?** *(About 25 percent)* **Absorbed by Earth's surface?** *(About 50 percent)*

Apply Remind students that the moon has no atmosphere. Ask: **If you were standing on the moon during the day, what color would the sky appear to be?** *(Black)* **Why wouldn't it be blue?** *(Without an atmosphere, there are no gas molecules to scatter the light and make the sky appear blue.)* **learning modality: logical/mathematical**

All in One Teaching Resources

- Transparency I12

Lab zone Teacher Demo L1

Absorption of Heat Energy

Materials several sheets of construction paper in white, black, and other light and dark colors; bandannas or other materials for blindfolds

Time 10 minutes

Focus Explain that not all parts of Earth's surface are heated equally by energy from the sun.

Teach Place the pieces of construction paper in direct sunlight. After five minutes, ask volunteers to put on blindfolds. Rearrange the order of the papers, and have students tell which papers are light and which are dark, according to how warm or cool the papers feel.

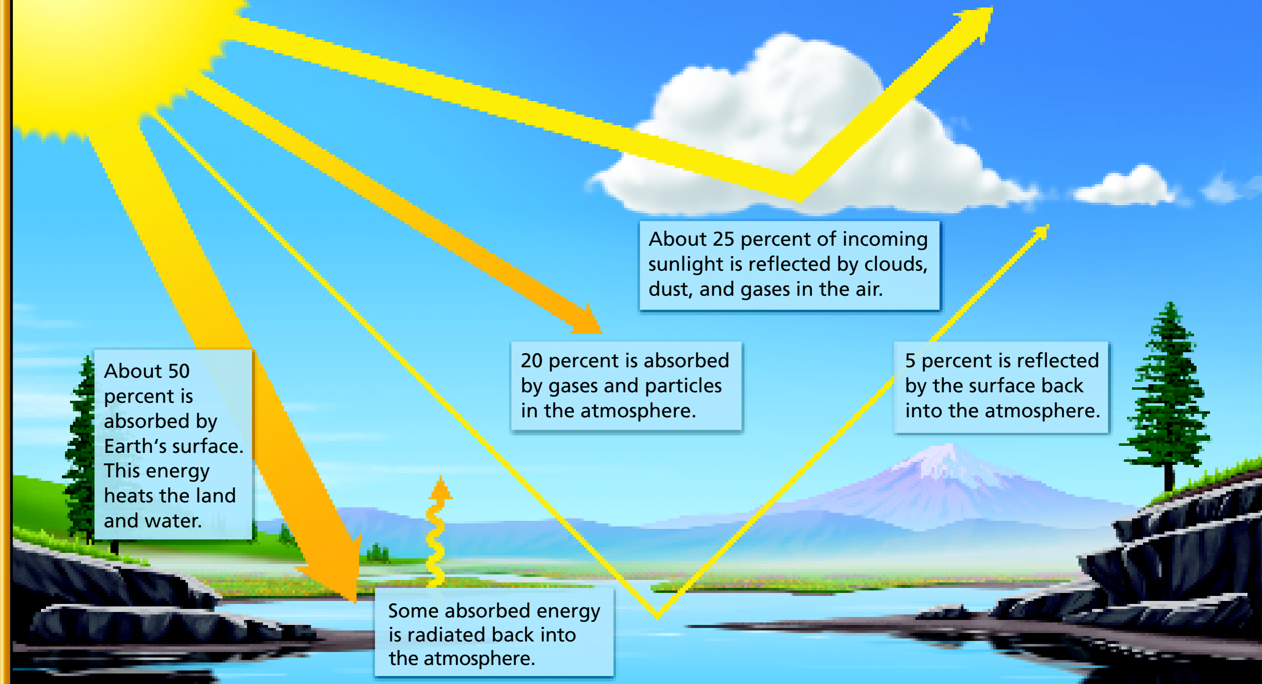

FIGURE 2
Energy in the Atmosphere
The sun's energy interacts with Earth's atmosphere and surface in several ways. About half is either reflected back into space or absorbed by the atmosphere. The rest reaches Earth's surface.

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Energy in the Atmosphere

Before reaching Earth's surface, sunlight must pass through the atmosphere. The path of the sun's rays is shown in Figure 2. **Some sunlight is absorbed or reflected by the atmosphere before it can reach the surface. The rest passes through the atmosphere to the surface.**

Part of the sun's energy is absorbed by the atmosphere. The ozone layer in the stratosphere absorbs most of the ultraviolet radiation. Water vapor and carbon dioxide absorb some infrared radiation. Clouds, dust, and other gases also absorb energy.

Some sunlight is reflected. Clouds act like mirrors, reflecting sunlight back into space. Dust particles and gases in the atmosphere reflect light in all directions, a process called **scattering.** When you look at the sky, the light you see has been scattered by gas molecules in the atmosphere. Gas molecules scatter short wavelengths of visible light (blue and violet) more than long wavelengths (red and orange). Scattered light therefore looks bluer than ordinary sunlight. This is why the daytime sky looks blue.

When the sun is rising or setting, its light passes through a greater thickness of the atmosphere than when the sun is higher in the sky. More light from the blue end of the spectrum is removed by scattering before it reaches your eyes. The remaining light contains mostly red and orange light. The sun looks red, and clouds around it become very colorful.

Apply Ask: **Why do the dark-colored papers feel warmer than the light-colored papers?** *(Dark-colored surfaces absorb more of the light that strikes them; light-colored surfaces reflect more of the light that strikes them.)* **What are examples of surfaces that reflect more of the sun's light back into space?** *(Possible answers: Sand or snow)* **Surfaces that absorb more?** *(Possible answers: Bare soil or blacktop pavement)* **learning modality: kinesthetic**

Energy at Earth's Surface

Some of the sun's energy reaches Earth's surface and is reflected back into the atmosphere. About half of the sun's energy, however, is absorbed by the land and water and changed into heat.

When Earth's surface is heated, it radiates most of the energy back into the atmosphere as infrared radiation. As shown in Figure 3, much of this infrared radiation cannot travel all the way through the atmosphere back into space. Instead, it is absorbed by water vapor, carbon dioxide, methane, and other gases in the air. The energy from the absorbed radiation heats the gases in the air. These gases form a "blanket" around Earth that holds heat in the atmosphere. The process by which gases hold heat in the air is called the **greenhouse effect.**

The greenhouse effect is a natural process that keeps Earth's atmosphere at a temperature that is comfortable for most living things. Over time, the amount of energy absorbed by the atmosphere and Earth's surface is in balance with the amount of energy radiated into space. In this way, Earth's average temperatures remain fairly constant. However, as you will learn later, emissions from human activities may be altering this process.

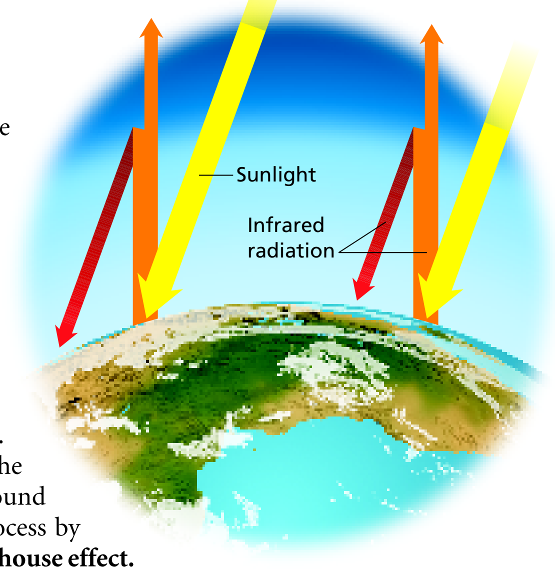


FIGURE 3
Greenhouse Effect
Sunlight travels through the atmosphere to Earth's surface. Earth's surface then gives off infrared radiation. Much of this energy is held by the atmosphere, warming it.

Reading Checkpoint **What is the greenhouse effect?**

Section 1 Assessment

Target Reading Skill

Sequencing Refer to your flowchart about how the sun's energy reaches Earth's surface as you answer Question 2.

Reviewing Key Concepts

1. a. **Listing** List three forms of radiation from the sun.
   b. **Comparing and Contrasting** Which form of radiation from the sun has the longest wavelength? The shortest wavelength?
2. a. Summarizing What happens to most of the sunlight that reaches Earth?
   b. **Interpreting Diagrams** What percentage of incoming sunlight is reflected by clouds, dust, and gases in the atmosphere?
   c. **Applying Concepts** Why are sunsets red?
3. a. **Describing** What happens to the energy from the sun that is absorbed by Earth's surface?
   b. **Predicting** How might conditions on Earth be different without the greenhouse effect?

Lab zone At-Home Activity

Heating Your Home With an adult family member, explore the role radiation from the sun plays in heating your home. Does it make some rooms warmer in the morning? Are other rooms warmer in the afternoon? How does opening and closing curtains or blinds affect the temperature of a room? Explain your observations to your family.

Lab zone At-Home Activity

Heating Your Home L1 Suggest to students that they do this activity on a sunny day, preferably when the furnace or another source of artificial heat is not operating.

Energy at Earth's Surface

Teach Key Concepts L1

The Greenhouse Effect

Focus Remind students that infrared rays can be felt as heat.

Teach Ask: **How does the greenhouse effect affect life on Earth?** *(The heat that is held in the atmosphere keeps Earth at a temperature that is comfortable for most living things.)*

Apply Ask students to recall the inside of a parked car on a hot, sunny day. Ask: **How is this like the greenhouse effect?** *(The windows in the car trap heat in a similar way as gases in the atmosphere do.)* **learning modality: logical/mathematical**

Monitor Progress L2

Answer

Reading Checkpoint The process by which gases hold heat in the air

Assess

Reviewing Key Concepts

1. a. Infrared, visible light, and ultraviolet **b.** Infrared, ultraviolet
2. a. It is absorbed by the atmosphere or by Earth's surface. **b.** About 25% **c.** At sunrise and sunset, sunlight travels through more atmosphere. The atmosphere scatters blue light but allows red light to get through.
3. a. It heats the land and water. **b.** Earth would be much colder.

Reteach L1

Have each student make a chart that shows what happens to sunlight that reaches Earth.

All in One Teaching Resources

- Section Summary: *Energy in Earth's Atmosphere*
- Review and Reinforce: *Energy in Earth's Atmosphere*
- Enrich: *Energy in Earth's Atmosphere*

Lab zone Skills Lab

Heating Earth's Surface

Prepare for Inquiry

L2

Key Concept

Sand heats and cools more quickly than water.

Skills Objectives

Students will be able to

- develop hypotheses about how quickly sand and water heat and cool
- create a data table to record their measurements
- measure the temperature of sand and water while these are heating and cooling
- make a graph showing their data
- draw conclusions from their data as to whether sand or water heats and cools more quickly

Prep Time 20 minutes
Class Time 40 minutes

Advance Planning

To allow time for students to record temperatures for a full 30 minutes, set up the equipment and measure out the sand and water ahead of time. Make sure that the sand is dry. Both sand and water should be at room temperature when the lab begins.

Alternative Materials

Students can use wide-mouth jars instead of beakers, as long as both jars are the same size and shape. Sugar can be substituted for sand.

Safety

Caution students to take care with the thermometers. All lab surfaces must be dry. Caution students to be careful not to splash water onto the light bulb.

All in One Teaching Resources

- Lab Worksheet: *Heating Earth's Surface*

Guide Inquiry

Invitation

Have students recall walking barefoot on a beach. Ask: **What was the temperature of the sand like?** *(Very warm or hot)* **When you reached the water, what was its temperature, compared to that of the hot sand?** *(It was much cooler.)* **If you have ever walked barefoot on the beach after dark, which felt warmer, sand or water?** *(Water)*

Lab zone Skills Lab

Heating Earth's Surface

Problem

How do the heating and cooling rates of sand and water compare?

Skills Focus

developing hypotheses, graphing, drawing conclusions

Materials

- 2 thermometers or temperature probes
- 2 beakers, 400-mL
- sand, 300 mL
- water, 300 mL
- lamp with 150-W bulb
- metric ruler
- clock or stopwatch
- string
- graph paper
- ring stand and two ring clamps

Procedure

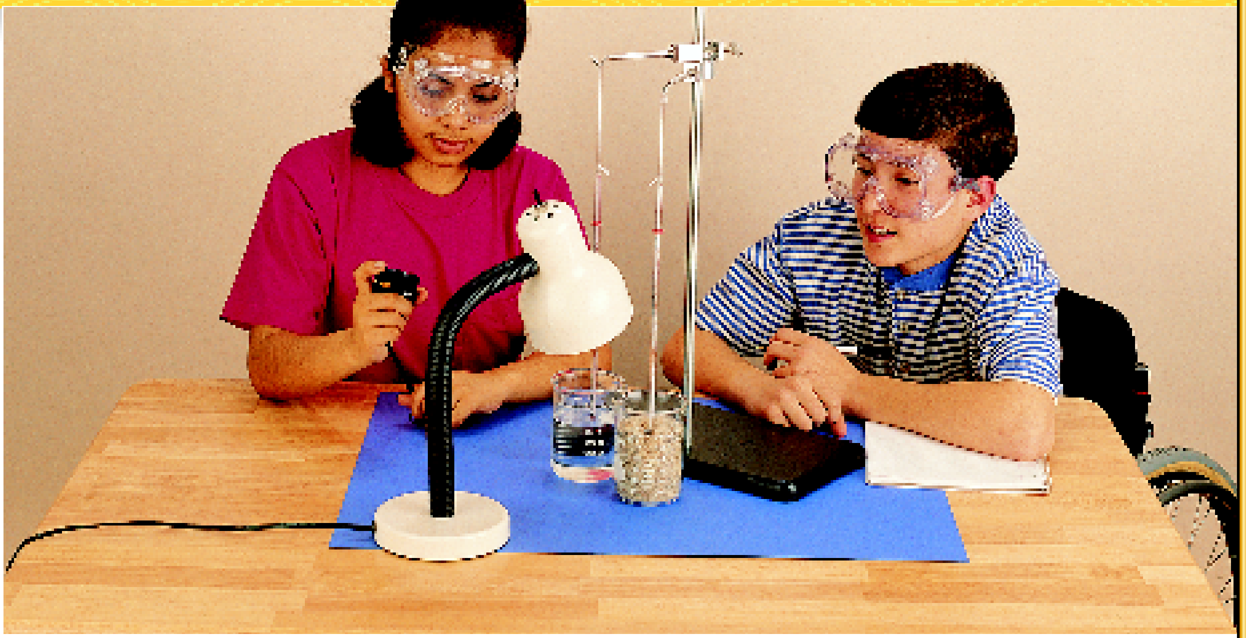
1. Which do you think will heat up faster—sand or water? Record your hypothesis. Then follow these steps to test your hypothesis.
2. Copy the data table into your notebook. Add enough rows to record data for 15 minutes.
3. Fill one beaker with 300 mL of dry sand.
4. Fill the second beaker with 300 mL of water at room temperature.
5. Arrange the beakers side by side beneath the ring stand.
6. Place one thermometer in each beaker. If you are using a temperature probe, see your teacher for instructions.
7. Suspend the thermometers from the ring stand with string. This will hold the thermometers in place so they do not fall.
8. Adjust the height of the clamp so that the bulb of each thermometer is covered by about 0.5 cm of sand or water in a beaker.
9. Position the lamp so that it is about 20 cm above the sand and water. There should be no more than 8 cm between the beakers. **CAUTION:** *Be careful not to splash water onto the hot light bulb.*
10. Record the temperature of the sand and water in your data table.
11. Turn on the lamp. Read the temperature of the sand and water every minute for 15 minutes. Record the temperatures in the *Temperature With Light On* column in the data table.
12. Which material do you think will cool off more quickly? Record your hypothesis. Again, give reasons why you think your hypothesis is correct.
13. Turn the light off. Read the temperature of the sand and water every minute for another 15 minutes. Record the temperatures in the *Temperature With Light Off* column (16–30 minutes).

Data Table

Temperature With Light On (°C)			Temperature With Light Off (°C)		
Time (min)	Sand	Water	Time (min)	Sand	Water
Start			16		
1			17		
2			18		
3			19		
4			20		
5			21		

Introduce the Procedure

Emphasize the importance of following each step of the procedure precisely. For example, students should use exactly the same amount of sand as water and place both beakers exactly the same distance from the lamp. Explain that by making these factors the same for both the sand and water, students will be controlling other variables that might affect the outcome of the experiment.



Analyze and Conclude

1. **Graphing** Draw two line graphs to show the data for the temperature change in sand and water over time. Label the horizontal axis from 0 to 30 minutes and the vertical axis in degrees Celsius. Draw both graphs on the same piece of graph paper. Use a dashed line to show the temperature change in water and a solid line to show the temperature change in sand.
2. **Calculating** Calculate the total change in temperature for each material.
3. **Interpreting Data** Based on your data, which material had the greater increase in temperature?
4. **Drawing Conclusions** What can you conclude about which material absorbed heat faster? How do your results compare with your hypothesis?
5. **Interpreting Data** Review your data again. In 15 minutes, which material cooled faster?
6. **Drawing Conclusions** How do these results compare to your second hypothesis?
7. **Developing Hypotheses** Based on your results, which do you think will heat up more quickly on a sunny day: the water in a lake or the sand surrounding it? After dark, which will cool off more quickly?
8. **Communicating** If your results did not support either of your hypotheses, why do you think the results differed from what you expected? Write a paragraph in which you discuss the results and how they compared to your hypotheses.

Design an Experiment

Do you think all solid materials heat up as fast as sand? For example, consider gravel, crushed stone, or different types of soil. Write a hypothesis about their heating rates as an "If ... then...." statement. With the approval and supervision of your teacher, develop a procedure to test your hypothesis. Was your hypothesis correct?

Troubleshooting the Experiment

- Make sure that each lamp is positioned so that it shines evenly on the two beakers. One beaker's receiving more direct rays than the other may bias the results.
- Both thermometers should be positioned the same distance below the surface and held in an upright position by the string.
- To reduce the number of setups needed, divide the class into groups and have each group use one setup.

Expected Outcome

The sand heats and cools more quickly than the water does.

Analyze and Conclude

1. Both graphs should rise steadily during the first 15 minutes and then decline steadily during the second 15 minutes. The line for sand temperature should rise and fall more steeply than the line for water temperature, indicating a greater rate of change in temperature for sand than for water.

2. The sand should show a greater total change in temperature than the water.

3. The data should show that the sand had a greater increase in temperature.

4. The sand absorbed heat faster than the water. These results may or may not agree with students' hypotheses.

5. The data should show that the sand cooled faster.

6. The results may or may not agree with students' second hypotheses.

7. The sand surrounding a lake will heat up more quickly on a sunny day and cool off more quickly after dark than the water in the lake.

8. Answers may vary. One possible answer is that students expected both the sand and water to heat and cool at the same rate because there were equal amounts of the two substances.

Extend Inquiry

Design an Experiment Students may think that solids with a different texture, made of different materials, or having different colors might heat up at different rates than sand. For example, students may think that rock would heat up faster than sand because it is more dense. Students may hypothesize that soil will heat up faster than sand because it is darker in color. They can test each hypothesis by repeating the skills lab with other materials.